

MCU—based Robotic Elbow Movement Control

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Abstract: *This paper proposes an MCU based robotic elbow movement control. In recent years, a lot of research has been developed in alignment with mimicking body movement especially in the field of medical and industrial applications. Robotic movement has different implementations. The usual method is through PID controller. However, implementation is complicated, response is slow, and movement control is delayed. Speed is also a problem causing the human arm and robotic arm not synchronized with their movement. In this paper, the fuzzy logic method is substituted to PID control. The MCU is used in the implementation of robotic elbow movement. The Experimental results are now carried out to demonstrate the effectiveness of the proposed technique and method. Results show that the proposed method is preferable and better over the conventional PID from response, delay, and also the movement control through three variable speed controls. Also, the movement control of the robotic elbow do synchronized with the human arms with negligible delay. In conclusion, the application of microcontroller does improve the movement of the robotic elbow. The switching response is faster and the delay is minimized caused by the PID control.*

Keywords: Elbow movement, Microcontrollers, Robotics, Speed control

I. Introduction

Mimicking is the act of imitating a behavior or movement of someone or something. In recent years, a lot of research has been done in the literature aligning with the mimic body movement especially in the field of medical. Extremities that have been removed can now be replaced by robotic artificial limb. A robot arms are versatile tools found in a wide range of applications. In recent years, applications where humans and robot arms interact have received increased attention to researchers. The case where the interaction entails the human controlling of a remote robot is called robot tele-operation [1]. This case requires a user interface to translate the operator commands to the robot. A large number of interfaces have been proposed on this issue in the previous research. However, most of them involve complex mechanisms or systems of sensors that the user should be acquainted with, resulting to a feeling of discomfort for non-experts. Among all the social infrastructure technologies, robotic technology is expected to play important role in electronics, computer, and

mechanical engineering. One of the most important fields in the development of successful robotics systems is then the human machine interaction (HMI) [1]. Robotic movement has different implementations. Some of these implementations do also require motors, servo, pneumatics, and even in the hydraulics [2]. The usual implementation is by means of the PID controllers. The other implementations have delays in the movement as caused by the processing or slow response of the device itself. Speed is also another issue for implementation causing the human and robotic arm do not synchronized in their movement. The main objective of this paper is to design a mimic robotic arm. Specifically, it intends to: (a) apply the concept of simple logic for the control of the robotic elbow simultaneous movement; (b) the design of a mechanical arm that has the same limitation and movement with the human arm; (c) the design of a circuitry that can produce the desired output with respect to its logic. The motion of the robotic elbow movement is dependent on the movement of the motor, maximum angle of the human elbow, and simultaneous motion based on the movement of the person wearing the specialized actuator. The minimum step of motion of the robot is 1.8 degrees, which is then the minimum angle of movement of servo motor. The controller is thus made up of potentiometer placed in the joint of the elbow. Potentiometer shall rotate as the elbow moves. This study then shall help improve existing robotic arms giving more freedom in doing precise works. This will sum up to the capability and performance of the robot. Performing additional functions such as painting, welding, screwing, surgical operation, patients who lose their arms and other related applications. This paper is organized as follows. Section II presents the basic theory of the robotic elbow movement. Also, the Section II describes the synthesis of robotic elbow movement using the microcontroller. Experimental results are then discussed in the Section III. The conclusion and the recommendation are finally given in Section IV.

II. Methodology

The movement created by the human arm and the robotic arm depends on the acceleration. To create a system suitable for the robotic arm to mimic the human arm, the relation of these two arms shall be discussed here. Firstly, the human arm analysis.

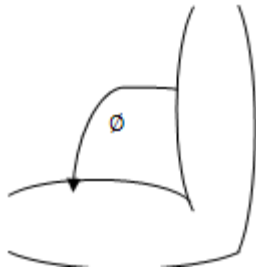


Fig. 1. The human arm.

The angular velocity of the human arm can be expressed as [5]:

$$v_{arm} = \frac{\Delta\phi}{\Delta t} = \frac{d\phi}{dt} \quad (1)$$

The potentiometer act as transducer in this case hence, the voltage that will be produced shall be proportional to the angular displacement of the arm.

$$\phi = k_{\sigma} v_{\xi} \quad (2)$$

therefore

$$v_{arm} = \frac{k_{\sigma} dv_{\xi}}{dt} \quad (3)$$

considering the acceleration of the human arm

$$a_{arm} = \frac{dv_{arm}}{dt} = \frac{k_{\sigma} d^2 v_{\xi}}{dt^2} \quad (4)$$

$$v_{arm} = \frac{1}{k_{\sigma}} \iint a_{arm} dt^2 \quad (5)$$

the voltage difference is expressed in terms of

$$v_d = \frac{1}{k_{\sigma}} \iint a_{arm} dt^2 - v_f \quad (6)$$

and the output voltage is

$$v_o = \frac{k_{\rho}}{k_{\sigma}} \iint a_{arm} dt^2 - v_f \quad (7)$$

the robotic arm controlled by a dc motor is illustrated below

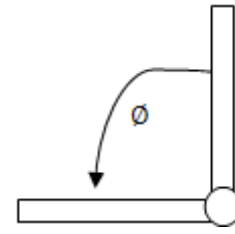


Fig. 2. The robotic arm.

the angular velocity of the robotic arm is varied by the amount of voltage applied in the DC motor

$$v_{rob} = k_{\zeta} \frac{\Delta\phi}{\Delta t} = k_{\zeta} v_{\chi} \quad (8)$$

$$dv_{\chi} = \frac{1}{k_{\zeta}} dv_{rob} \quad (9)$$

considering the acceleration of the motor, it depends on the motor coil to charge energy to rotate, which is the transient of the inductor

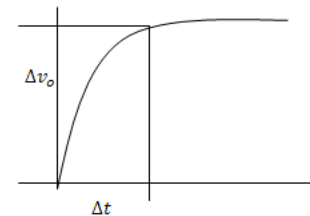


Fig. 3. Acceleration in the motor.

where

$$c = \frac{dv_{rob}}{dt} \quad (10)$$

therefore

$$a_{rob} = \frac{dv_{\chi}}{dt} = \frac{1}{k_{\zeta}} \frac{dv_{rob}}{dt} \quad (11)$$

The researchers aim to show that changing only the velocity without considering the acceleration shall produce the same movement or displacement with respect to time, using only the concept of digital switching of voltage via MCU. Changing some few voltages output that will produce few angular velocity, shall create the same angular displacement with respect to time. The proposed system shall possess the following functions: (a) an ability to sense the difference of angle between the human elbow and the robotic elbow, (b) the ability to change voltage value with respect to the change of displacement, and (c) the

system has the ability to convert analog signal to digital for the processing of MCU. The researchers made use of the following specifications (a) Sensing: Potentiometer (angular displacement) (b) Microcontroller: PIC16F877(ADC conversion), (c) MCU compiler: Microcode studio (coding), (d) Output: DC Motor, (e) Power supply: 12V, 5V, 3V, 1V (represents variable speed of the robotic elbow movement), (f) Speed sensing: Instrumentation amplifier (for the error representation). In the Fig. 4. it shows the conceptual framework of the researchers used to achieve the desired movement of the robotic elbow. The human elbow shall provide the initial movement for the robotic elbow to follow. The two transducers which are potentiometers shall convert the movement to electrical signal both for the human and robotic elbow. The differential amplifier shall perform subtraction to this two voltage level to know if there is an initial movement created. The voltage differences shall also serve as the indicator of how much voltage the system shall give to indicate the right velocity for the motor. The analog to digital converter (ADC) shall be used to make the digital signals and to make it suitable for the processing. The MCU shall then control the switching system to give the right voltage for the corresponding velocity, which will depend then on the logic or program stored in the microcontroller. Likewise, from the measurements gathered, the proponents created by the 3D graphical model using AutoCAD application software for computer-aided design and drafting, which resembles the actual measurements of the robotic elbow. The researchers used the software to determine the minimum and maximum dimension needed to create the system through simulation test at different position, angle, and orientation. Also, the schematic diagram in Fig. 5.b represents the component and their connection as it is used in the circuit development. The Proteus ISIS Professional software is used for the creation of the schematic because it has the capability of performing real-time simulation.

III. Experimental Results

The researchers first set the range of angle displacement as reference to the values needed through with the help of spreadsheet, the limits of maximum and minimum values are derived. Below are the tables for the summary of values. Also, all electronics component, materials, and module that are used in the development of the system are commercially available in the local market. The whole device worked properly and produces expected output during actual field testing.

Table 1. Data values and results.

Angular Displacement	Voltage difference (Lower Limit)	Voltage difference (Upper Limit)	Binary Values (Lower Limit)	Binary Values (Upper Limit)	Difference Between Upper and Lower Limit	Rounded Value of Difference Between Upper and Lower Limit
72.5	0	1.46484375	0	75	-2.5	-2.5
29.453125	1.484375	1.953125	76	100	-1.015625	-1
15.29296875	1.97265625	2.4609375	101	126	-0.52734375	-0.5
1.1328125	2.48046875	2.51953125	127	129	-0.01953125	0
15.29296875	2.5390625	3.02734375	130	155	0.52734375	0.5
29.453125	3.046875	3.515625	156	180	1.015625	1
72.5	3.53515625	5	181	256	2.5	2.5

Change of displacement	"0.1<=<0.25"	"0.5>=>0.1"	"0>=>0.5"	0	0<=<0.5	0.5<=<0.1	0.1<=<0.25
fast	CCF	CCM	CCS	CCS	CS	CM	CF
moderate	CCF	CCM	CCS	CCS	CS	CM	CF
slow	CCF	CCM	CCS	CS	CS	CM	CF
stop	CCF	CCM	CCS	S	CS	CM	CF
slow	CCF	CCM	CCS	CCS	CS	CM	CF
moderate	CCF	CCM	CCS	CCS	CS	CM	CF
fast	CCF	CCM	CCS	CCS	CS	CM	CF

Below summarizes the result of the evaluation.

Area of testing		Findings	Comment
Accuracy		There is 4 degree difference with respect to the expected output	It is due to mechanical aspect of lacking in the proper calibration that hinder the response
RESPONSE	Speed	Robot arm derived the same point with respect to human arm.	Although different speed exhibit by the robot arm, somewhat it create illusion of the same speed.
	Delay	There is no significant delay between the response of the human arm and robotic arm.	Delay is acceptable

IV. Conclusion

Based on the experimentation and evaluation conducted by the researchers, it is concluded that the logic application of micro controller improved the movement of the robotic elbow in terms response because of the switching process is good and faster. The proposed method eliminates the delay cause by the PID controller. The speed of the robotic elbow is compared with the speed of the human elbow. The developed system is found to be sufficient to perform its function. However, some modifications can be advised by the researchers for optimal performance of the system. Hence, the following recommendations are suggested: (a) the speed of the robotic arm is dependent to the three voltage level, adding more voltage level could refine the elbow movement speed of the robotic arm; (b) mechanical switches contribute to the delay of the response. It is suggested to use fast switching device.

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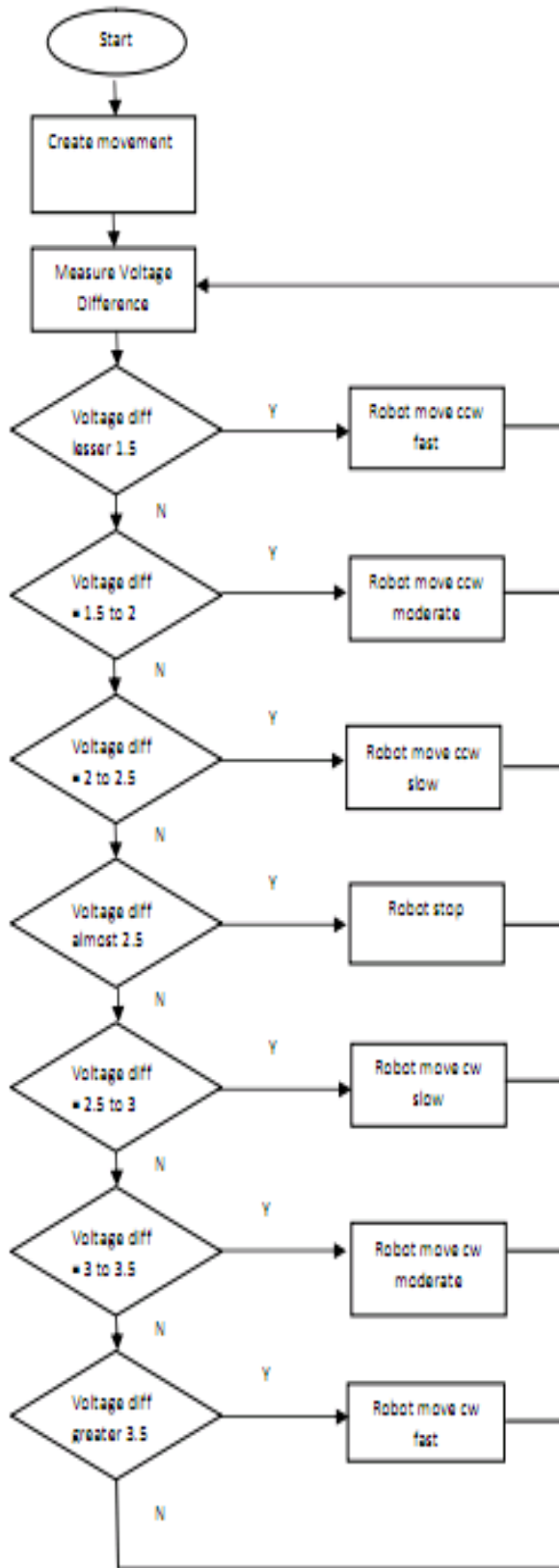


Fig. 4. Flow chart response of robotic elbow movement.

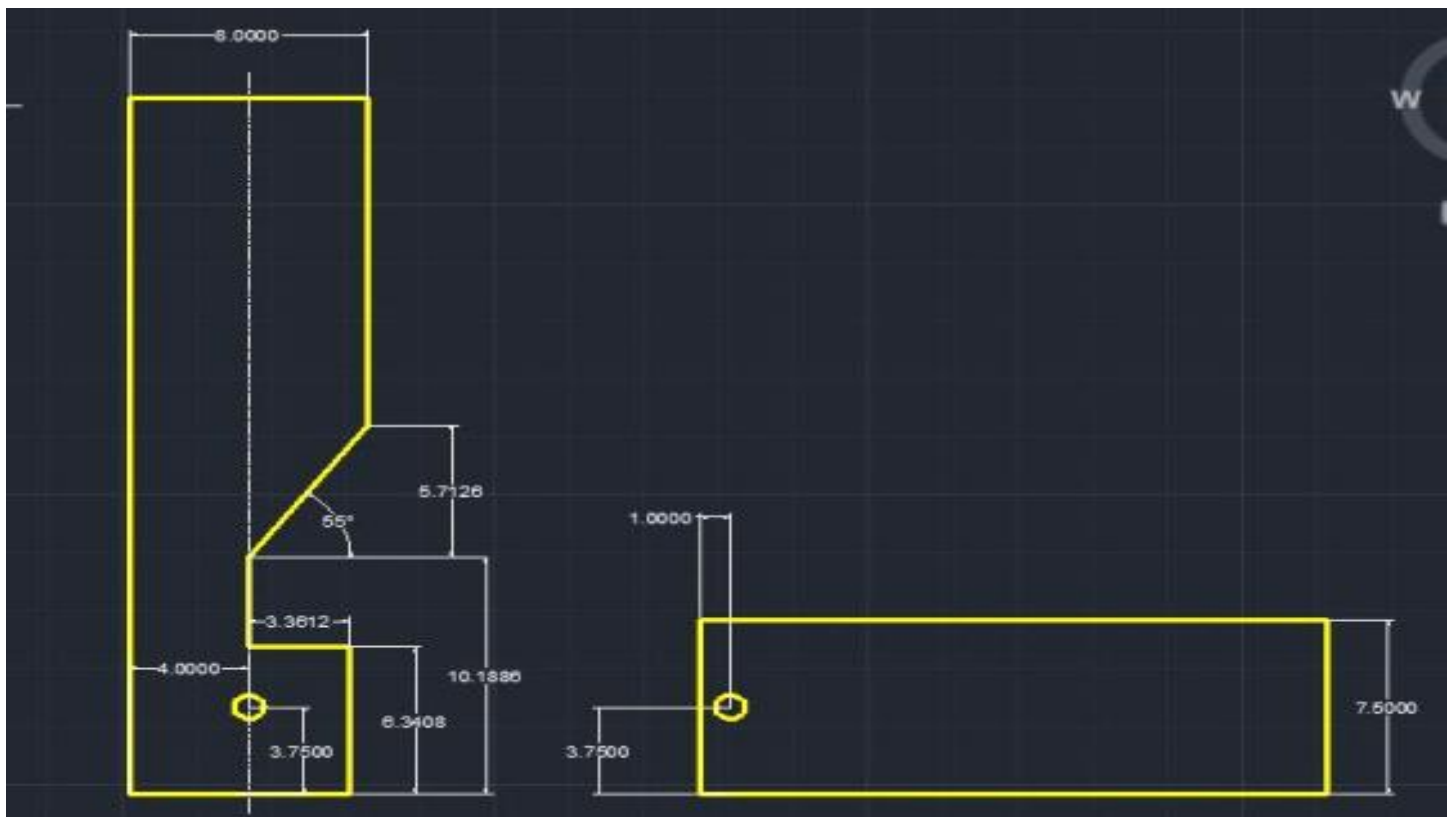


Fig. 5. (a) mechanical design using AutoCAD, (b) schematic diagram of the robotic elbow system using Proteus ISIS

